DESIGNING THE MODERN ENGINE

PART VIII

Driving the Accessories

BY ROGER HUNTINGTON

A FEW YEARS ago the matter of engine accessories would hardly have warranted a separate article. The starter and generator were about all there were. Today, with the increasing popularity of electrical power devices, hydraulic power steering and air conditioning, it's a fact that the engine power required to drive this accessory load will often exceed the power required to drive the whole car at legal city vehicle speeds! Accessories are no longer a sideline around Detroit.

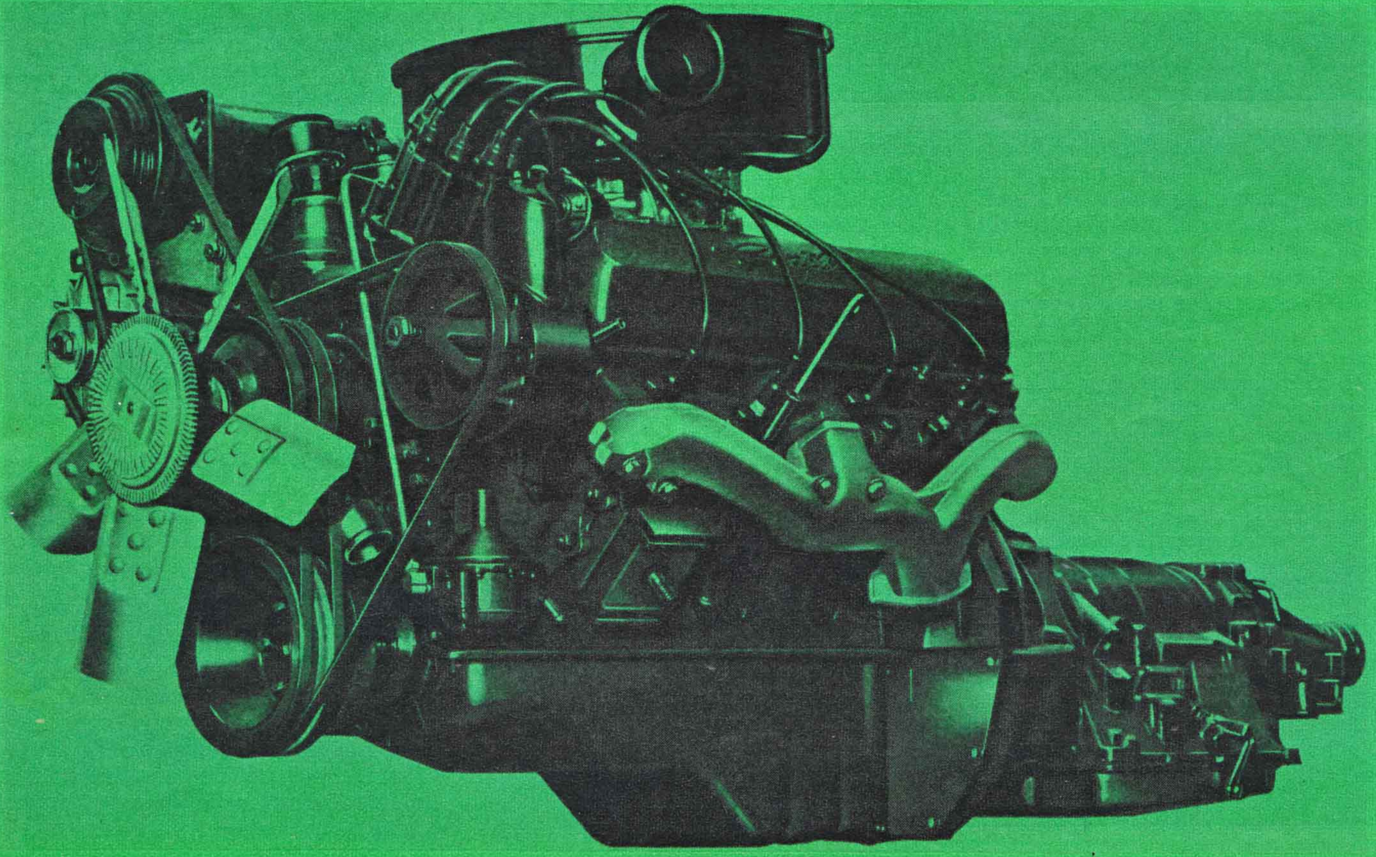
As long as cars aren't driven around connected to an overhead power line or a long extension cord, the self-contained electrical system based on a storage battery and engine-driven direct current generating system is just about a must.

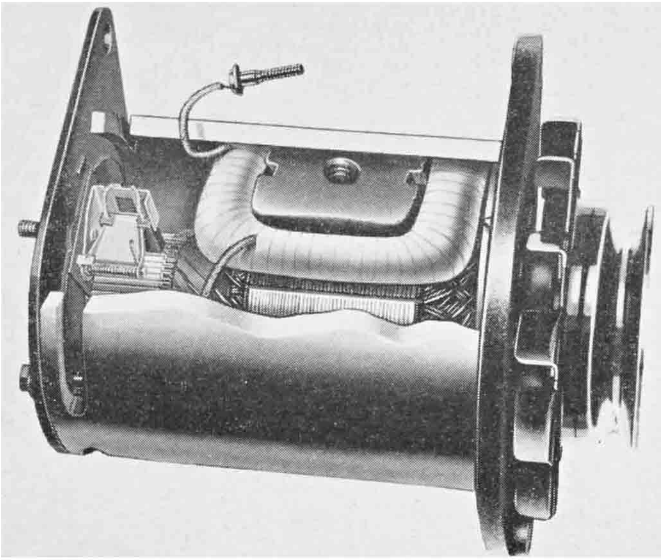
The biggest development in this area in the last few years is the switch from the d.c. generator to the alternating current "alternator" with silicon diode rectifiers (to convert the a.c. output to d.c. to charge the battery). The alternator has several important advantages over the age-old generator. For one thing, it delivers a substantial current output with the engine idling or at very low car speeds—whereas the d.c. generator doesn't have any appreciable output below 10 or 15 mph car speed. (The generator could be geared up to give the needed output at low speeds, but then it would be spinning too fast for durability at high car speeds.) With the high electrical loads of modern cars running in stop-and-go city traffic there was a great need for this extra low-speed output. The alternator was an inevitable development.

The essential feature of the alternator is that it has the field coils in the rotating armature, instead of stationary around the casing like the generator. Thus the lines of magnetic force form two closed loops. This permits placing several sets of current windings around the outside of the armature, so that more lines of force will be cut and the output will be increased. Modern automotive alternators generally carry three sets of windings or coils in the stator. This gives three surges of voltage each revolution (called 3-phase output) instead of the two surges given by the conventional d.c. generator with stationary field coils. Thus the alternator current output is potentially 50% greater at a given rotational speed. And more stator windings could be used if greater low-speed output were needed.

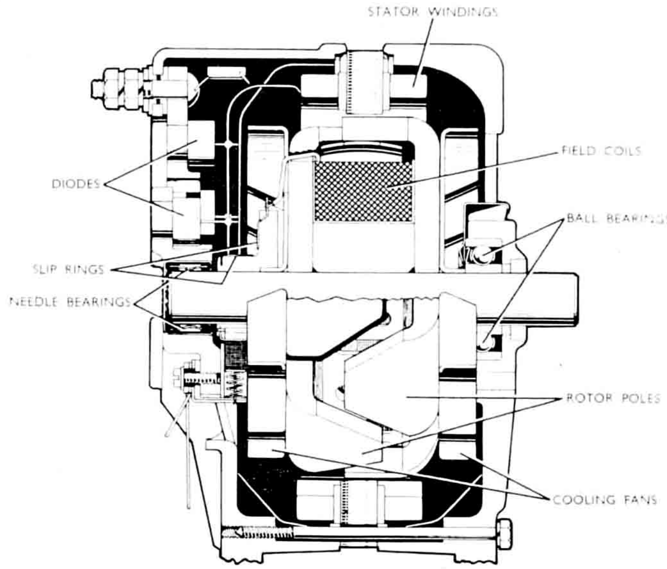
The alternator also has inherently longer life than the d.c. generator. The generator armature produces an alternating current, and this must be rectified to d.c. by a split-ring commutator feeding to sliding brushes. These brushes must carry the full generator output, and slide on a more or less jagged surface. Brush life is a serious problem. With the alternator the brushes only need to carry the small field current of 3 amperes or so and ▶

CADILLAC V-8 is especially designed to meet modern power needs, has drive system for power steering, air conditioner and alternator incorporated onto front of engine.





TYPICAL D.C. generator (Ford Fairlane): Field coils are stationary and there are only two power surges per revolution.



ALTERNATOR HAS field coils on rotating armature, giving magnetic field of two closed loops, more coils on outside.

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they ride on smooth slip rings connected to the field coils in the armature. The high-current output from the stator windings is rectified by six silicon diodes (three positive, three negative) which act literally as one-way valves for electrical current. The current output is still in surges, but they all go in the same direction after being rectified in the diode bank. Meanwhile, the alternator brushes carry only a very small current on smooth slip rings, so are said to last three times as long as the high-current commutator brushes on a d.c. generator.

One other advantage of an alternator is that it requires a simple single-unit voltage regulator. A d.c. generator requires separate point units to cut off output at high rpm (as the current would keep on increasing in more or less direct proportion with engine speed) and another current reversal switch is needed to prevent back-flow from the battery. With an alternator the diodes prevent back-flow from the battery and electrical inductance levels off the output at high rpm. This means a single-unit voltage control and two fewer things to go wrong.

The switch from 6- to 12-volt electrical systems in the mid '50s was made primarily to increase the available spark voltage for more reliable ignition under marginal conditions (such as cold starting and high rpm). Secondary advantages were more economical wiring, since the current flow for a given wattage is inversely proportional to the voltage, and a higher ampere-hour capacity for a given bulk and weight of battery. Improved battery construction, with better insulation and plate materials and better sealing has helped, too. The higher voltage system also made it more practical to employ small, fractional horsepower electric motors scattered around the car to do various jobs like raising windows, convertible tops, moving seats and operating high-flow heater blowers. Today's "push-button" car could be hardly practical with a 6-volt electrical system.

The most interesting advancement in starters in the past few years was Chrysler's adoption of the low-torque, low-speed concept. Starter motors on current Chrysler products develop only about half the torque of equivalent starters on other cars—and cranking speeds of 35 rpm, compared with 150 to 250 rpm on other cars. Obviously the advantage was a starter motor that was much smaller, lighter and cheaper. The lower torque is enough to do the job in cold weather at 35 rpm cranking speeds—so it was all a question of whether 35 rpm was fast enough for quick starting. Chrysler engineers think it is, but most of the rest of Detroit thinks it isn't.

Many automotive enthusiasts don't realize that hydraulic power used to be more popular on American cars than it is today. Back in the '40s and early '50s most of the power tops, windows and seats were hydraulically operated. There was generally one central hydraulic pump, driven by a husky electric motor, and this fed oil at up to 250 psi pressure through flexible lines to individual power cylinders at each operating component. It was felt that this system was more practical than doing the work directly with individual electric motors. However, the small fractional horsepower motor was not highly developed in those days, wiring and switching was less reliable and 6-volt electrical systems didn't lend themselves well to high power demands.

In the mid '50s Borg-Warner's Pesco division made quite a hoop-la about a central hydraulic system it had developed for passenger cars. It used one big engine-driven variable-displacement hydraulic pump, feeding to an accumulator to store the pressure. And Pesco was all for operating everything but the road wheels with hydraulic power. Pesco had special hydraulic motors to operate the seats, windows, top and steering gear—even the generator, windshield wipers and cooling fan! The system also included provision for operating the brakes with a hydraulic booster fed by pressure from the central accumulator. Instead of wires, the body was laced with oil lines! Pesco people claimed considerable power and fuel savings by storing stand-by hydraulic power in an accumulator instead of storing electrical energy in a battery to operate individual motors. They said the energy conversion was more efficient and that the individual hydraulic motors were cheaper and simpler than small electric motors.

The central hydraulic system was a big topic of conversation around Detroit ten years ago. Those early examples were merely assist mechanisms to add some force to the conventional manual steering gear. Pump capacity of 0.9 gal./min. at 750 psi pressure (engine idling) was adequate and control valves were crude by today's standards. Most current power steering mechanisms are built integral with the gear unit at the base of the steering column. They provide practically all the force necessary to steer the front wheels. The control valves are preloaded to give the driver some "feel" of the steering, but this is only 1-2 lb. of rim force on Chrysler products with "full-time" power steering. (Ford and General Motors lines lean toward 4-6 lb. rim force for more feel.) Under these conditions pump requirements zoom up. Modern power steering pumps deliver about 1.75 gpm at 1100-1300 psi at idling speed but they can readily eat up 2-3 bhp.

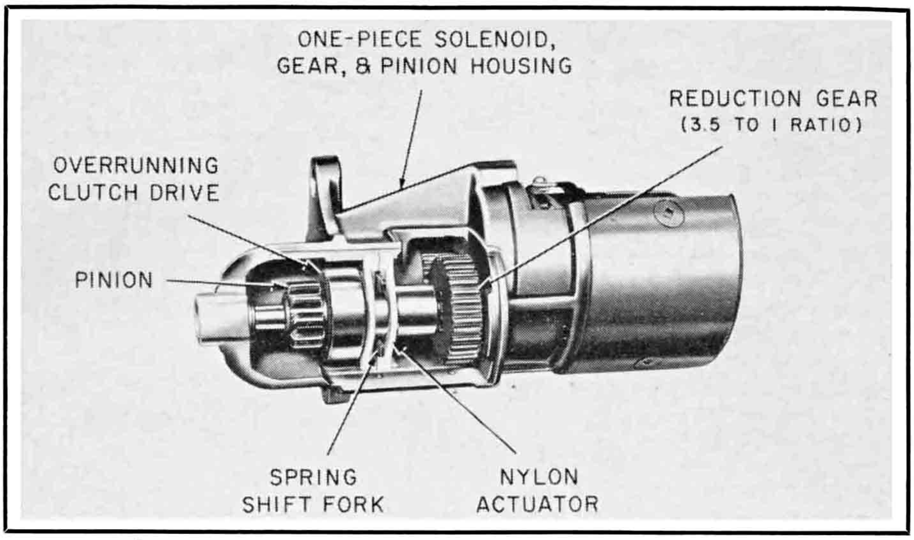
Air conditioning is the fastest-growing accessory on American cars—even at prices of $300 to $500! And the modern systems are much more compact and practical than the nightmares of the early '50s—where the cooling coils were in the trunk, ducts were built into the roof, plumbing was all through the car and a by-passing refrigeration compressor sapped bhp even in winter. Today's compact, one-unit systems under the cowl, with a magnetic clutch on the compressor, are a hundred times more practical. Cadillac's new integrated heating and cooling system has a dial where the driver can set one temperature that will be automatically maintained winter and summer . . . well, where can they go from here?

The design of the refrigeration compressor has been especially interesting. General Motors' Frigidaire division engineers chose the 6-cyl. barrel-type pump for their modern compressor unit. This has a wobble or "swashplate" on the axial shaft that bears against three double-ended pistons (through ball rollers) and causes them to reciprocate in axial cylinders. In effect there are six cylinders, since each end of the three pistons pump once each revolution. The bore is 1.5 in. and the stroke 1.1875. Maximum displacement is 12.6 cu. in. per revolution. At a car speed of 60 mph the compressor turns 3150 rpm and develops some three tons of refrigeration—or enough to air-condition an average 7-room home. The compressor requires 10.3 bhp to drive it under these conditions.

It's hard to imagine the sophisticated engineering that goes into a seemingly simple auto accessory such as this. The mass of the swashplate has to be calculated to counterbalance reciprocating inertia forces of the pistons. Shaft seals must be carefully designed to keep compressor sump oil from getting into the refrigerant. A rubber coupling was necessary between pulley and driveshaft to eliminate torsional vibration periods. A very compact magnetic clutch was devised between drive pulley and shaft. The energizing coil is attached to the compressor casing and sealed with epoxy, which gives complete protection against dirt and moisture and eliminates the need for sliding brushes on a rotating coil that can wear out. The magnetic lines of force from the coil pull an iron-core drive plate back against the non-magnetic pulley assembly to complete the magnetic circuit. The friction and magnetic pull of the drive plate against the pulley is enough to transmit the necessary 10-12 bhp. Also, isolating the drive plate from the pulley relieves the compressor shaft of any pulley belt loads. The whole thing is built to run 75,000 miles without attention. And there's no drag whatever when the cooling isn't on.

It's hard to predict just which way power accessories will go in the foreseeable future. Certainly more such accessories are likely—that is, accessories supplied by power from the engine (whether electrical, hydraulic or vacuum). But it seems as though there should be some well-defined trend toward using one or the other form of power exclusively. So far there is definitely no such trend. For instance we now use hydraulic power pretty much only for the steering. But here's Lincoln running along very nicely with hydraulically-operated windshield wipers. Then there's intake manifold vacuum as a cheap and practical power source. Right now it's used mostly for power brakes. But some makers use it to open valves in heater ducts; Buick and Pontiac use vacuum to operate the throttle rod in their "Speed Control" systems; and others use it to operate power antennas. Perhaps there could be more applications—vacuum cylinders were used to raise and lower convertible tops around 1940.

Then the old system of electric motors and solenoids has some interesting possibilities left. There are the usual applications, like power windows, seats, windshield wipers and washers. But now there are the new GM automatic transmissions with solenoid-operated kickdown switches in place of the old mechanical linkage. How many more of these applications might there be? What about power throttles as well as brakes and steering? Apparently the surface hasn't even been scratched. ■



LOW-TORQUE STARTER by Chrysler uses 3.5:1 reduction gears to get enough force to start engine at 35 rpm cranking speed. Unit is much smaller, cheaper and lighter.

COMPARATIVE OUTPUTS of alternator and generator at different engine speeds. Note alternator's higher output at low speeds. Regulator keeps generator from overcharging.